TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 656

DYNAMIC TESTING OF AIRPLANE SHOCK-ABSORBING STRUTS

By P. Langer and W. Thomé

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SUMMARY

Measurement of perpendicular impacts of a landing gear with different shock-absorbing struts against the drum testing stand. Tests were made with pneumatic shock absorbers having various degrees of damping, liquid shock absorbers, steel-spring shock absorbers and rigid struts. Falling tests and rolling tests. Maximum impact and gradual reduction of the impacts in number and time in the falling tests. Maximum impact and number of weaker impacts in the rolling tests.

The object of the tests was the determination of the shock-absorbing characteristics of different airplane shock-absorbing struts.**

For the tests there were placed at our disposal:

1. One Rheinmetall Faudi pneumatic shock absorber A. (Fig. 1.)

2. One each of Rheinmetall Faudi pneumatic shock absorbers B and C. (Fig. 2.)

3. One Rheinmetall liquid shock absorber. (Fig. 3.)

4. One steel shock absorber with a helical spring of 32 mm (1.26 in.) wire, a mean coil diameter of 156 mm (6.15 in.) and 16 turns.

5. One rigid tubular strut.

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* "Dynamische Untersuchung von Flugzeugfederbeinen." Zeitschrift des Vereines deutscher Ingenieure (V.D.I.), November 7, 1931, pp. 1388-1389.

** The investigation was undertaken at the request of the Rheinmetall Company on a test stand in their factory at Düsseldorf-Derendorf.

The following method was employed in testing the pneumatic and liquid shock absorbers:

Pneumatic shock absorber A (fig. 1).- The air cushion in the compression cylinder exercises the damping effect. When the piston is driven in, air flows into the free space on the upper side of the piston through snifting valves and forms a cushion for the piston.

Pneumatic shock absorber B (fig. 2).- The compression space $a_1 + a_2$ is divided by a partition e into two separate compression chambers a_1 and a_2. This partition has two openings f of 5 mm (0.2 in.) (.008 in.) diameter and several openings g which are closed by a rubber pad. When the piston is driven in, the air is condensed in chambers a_1 and a_2, raises the pad and flows through the openings g. As the strut lengthens again, the rubber pad closes the openings g, the air generally expands in the compression chamber a_1 and the air flows from the compression chamber a_2 through the throttle openings f into chamber a_1. The pneumatic shock absorbers B and C, however, have only one opening f of 5 mm (0.2 in.) in the partition of the compression cylinder.

Liquid shock absorber (fig. 3).- When the piston is driven in, the air in the space a is condensed; the liquid flows through the annular opening b, whose cross section is controlled by the spindle c, into the space a with increasing throttling effect.

Testing mechanism.- This is shown in Figures 4 and 5. The frame representing an airplane fuselage with a loading box b was hinged on one side and was supported on the other side by two struts d and the shock absorber with the wheel resting on the drum f of 2.32 m (7.61 ft.) diameter. This drum could be provided with an obstacle and was driven by a belt from an electric motor. The total weight of the frame with load was 4000 kg (8818 lb.). On the loading weight, at the C.G. of the entire system, was placed the Langer-Thomé accelerometer g with various pendulums and cable connections with a recording magneto on a side table. The distance of the accelerometer from the axis of rotation of the frame was 2.1 m (6.89 ft.).

The tests.- The airplane shock-absorbing struts were tested by measuring the force of the impacts in falling and rolling tests. In the falling tests, with the drum at rest,

the frame was raised by means of a hook and allowed to fall freely by releasing the hook. Measurements were made of the falling distance h (between the top of the drum and the bottom of the unloaded tire (fig. 4)) and of the force of perpendicular impact of the fuselage from different heights at the location of the accelerometer.

In the rolling tests the frame was first raised so high that the obstacle on the revolving drum could pass under the tire with about 5 mm (0.2 in.) clearance. The obstruction was a cam 135 mm (5.31 in.) high with tangential approaches and covered about one-third of the circumference of the drum. The drum was given a revolution speed corresponding to the desired initial rolling speed; the electric motor was switched off; the frame was allowed to fall by releasing the hook; and the whole system (frame, drum, belt and motor) allowed to run until stopped by its own resistance. The perpendicular impact forces were measured by the accelerometer. The rolling test represents the impacts of an airplane in taking off and in landing.

Experimental results.- The maximum accelerations and retardations in the first impact from various heights and the reduction in the impact force according to the number and time are decisive for the apprasial of the shock absorbers according to the results of the falling tests. The plotted values for the shock absorbers tested are compared in Figures 6 to 8. The pneumatic shock absorbers A, B and C and the liquid shock absorber are equivalent as regards the maximum accelerations and retardations in the first impact. (Fig. 6.) The impact forces diminish most rapidly with the pneumatic shock absorber C and the liquid shock absorber, and indeed equally fast for both. With the pneumatic shock absorbers A and B, the steel-spring shock absorber and the rigid strut, the impacts diminish more slowly for the lack of sufficient damping. (Figs. 7 and 8.)

According to the results of the rolling tests, primarily the maximum inpact and secondarily the frequency of the weaker impacts are decisive for the appraisal of the shock absorbers. The accelerometer records were therefore evaluated according to the number of impacts. Hence a count was made of how often, during the whole run, the impact forces exceeded the magnitudes corresponding to the individual extensions of the measuring pendulums. Against the thus-determined number of impacts (for each run) as abscissas, was plotted the magnitude of the corresponding impact forces (in terms of the acceleration) as ordinates.

In Figure 9 the maximum impacts of the various shock absorbers recorded in the rolling tests are plotted against the initial rolling speed.

The well-damped pneumatic shock absorber C showed the smallest maximum impacts. For example, while the impact of 40 m/s^2 (131.2 ft/sec^2) was first reached with the pneumatic shock absorber C at an initial rolling speed of 93 km/h (57.8 mi./hr.), this impact occurred with the pneumatic shock absorber B at 86 km/h (53.5 mi./hr.), with the liquid shock absorber at 63 km/h (39.2 mi./hr.), with the steel-spring shock absorber at 50 km/h (31 mi./hr.), with the pneumatic shock absorber A at 43 km/h (26.7 mi./hr.), and with the rigid strut at only 35 km/h (21.8 mi./hr.). The almost undamped pneumatic shock absorber A already showed, at an initial rolling speed of 42 km/h (26.1 mi./hr.), such violent resonance vibrations that the tests with this shock absorber had to be discontinued.

The frequency curves found by the enumeration method for the various shock absorbers at the initial rolling speeds of 30, 60, and 90 km (18.6, 37.3 and 55.9 miles) per hour are compared in Figs. 10-12. The impacts are the weakest with the well-damped pneumatic shock absorber C, the comparison of which with the rigid strut shows plainly, how large the gain obtained by the pneumatic shock absorber is. In the appraisal of the shock absorbers, the most weight must be given the results of the rolling tests. Pneumatic shock absorbers with adequate damping were found superior to all the other shock absorbers tested.

Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics

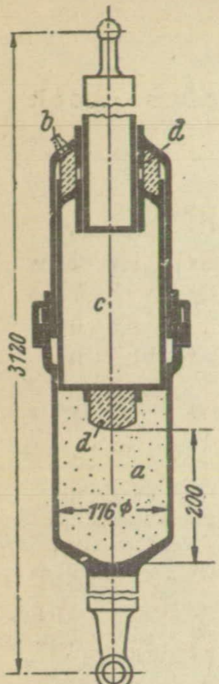


Fig. 1

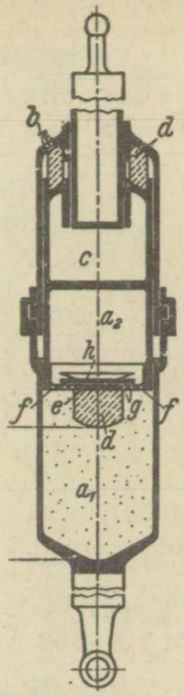


Fig. 2

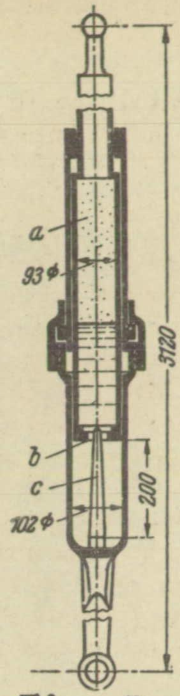


Fig. 3

Figs.1 & 2
Rheinmetall-Faudi pneumatic shock absorbers for airplanes.

a, a_1, a_2, cylinders filled with compressed air. b, snifting valve. c, piston. d, rubber cushion. e, partition. f, openings in partition e. g, openings in partition e, closable by h. h, rubber pad.

Fig. 3
Rheinmetall-Faudi liquid shock absorber. a, piston: compressed air above, liquid below. b, annular opening. c, spindel.

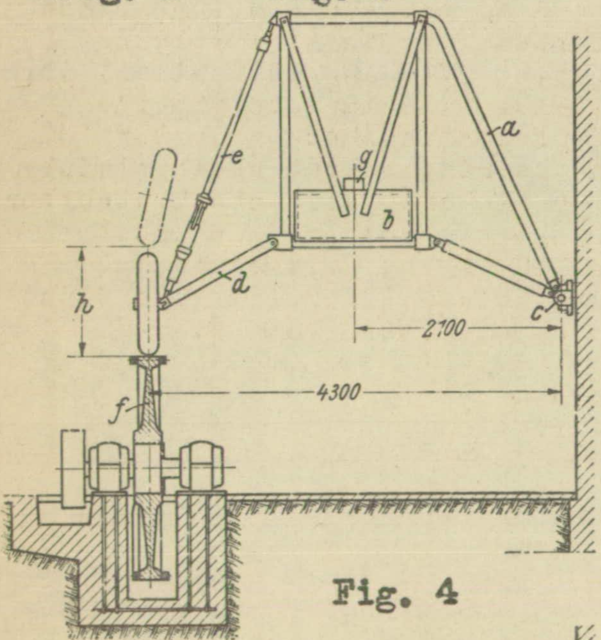


Fig. 4

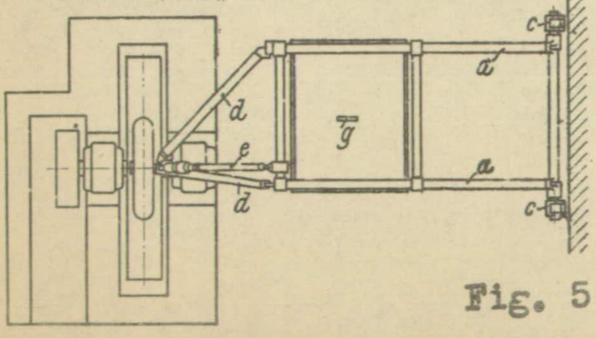
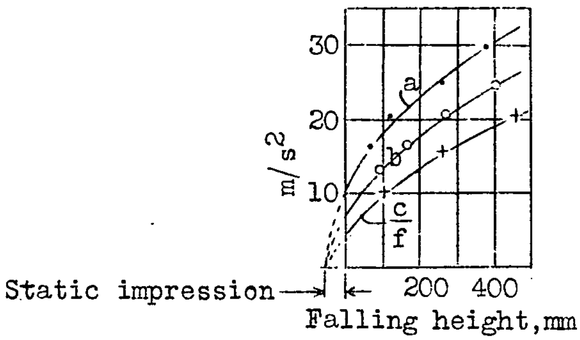


Fig. 5

Figs.4 & 5
Mechanism for testing shock absorbers.

a, frame representing airplane fuselage. b, loading box. c, hinge. d, strut. e, shock-absorbing strut. f, drum. g, accelerometer. h, falling height.



a,Rigid stut
b,Steel-spring shock absorber
c,Liquid shock absorber
d,Pneumatic shock absorber A
e, " " " B
f, " " " C

Fig.6 Comparison of shock absorbers according to falling tests; first impact at various heights.

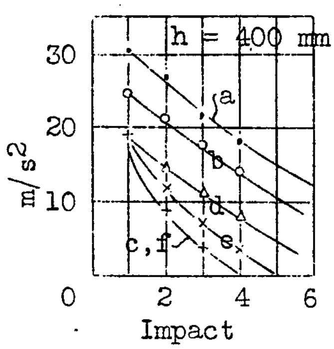


Fig.7

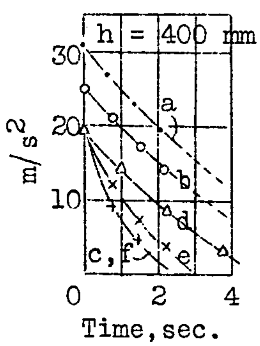
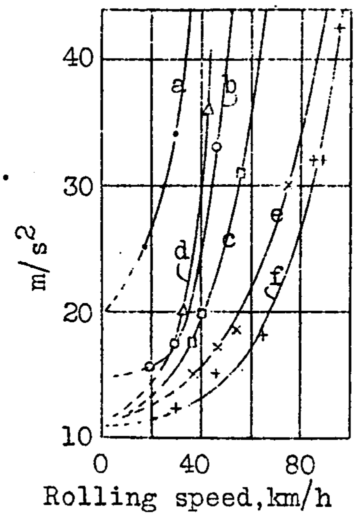


Fig.8

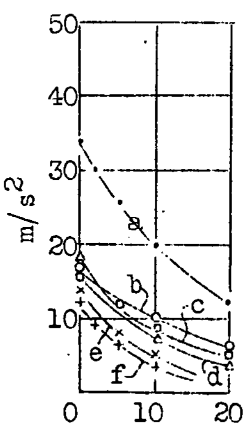
Figs.7,8 Diminishing of impacts according to number and time in falling tests.

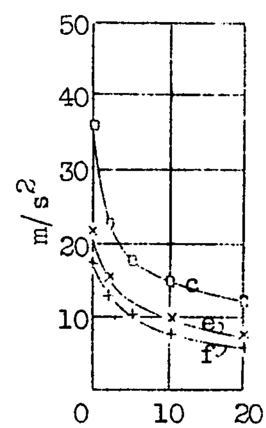
a, Rigid strut.
b, Steel-spring shock absorber.
c, Liquid shock absorber.

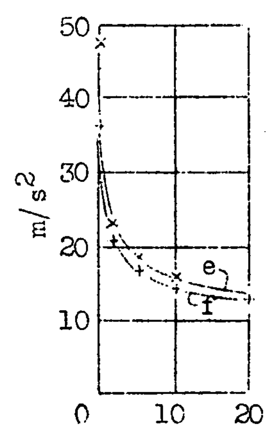


d, Pneumatic shock absorber A.
e, Pneumatic shock absorber B.
f, Pneumatic shock absorber C.

Fig.9 Comparison of shock absorbers according to rolling tests. Maximum impact during run at various rolling speeds.







Number of impacts per run

Fig.10 Number of impacts at 30 km/h

Fig.11 Number of impacts at 60 km/h. Rigid strut, steel-spring shock absorber and pneumatic shock absorber A could not be used.

Fig.12 Number of impacts at 90 km/h. Rigid strut, steel-spring shock absorber, pneumatic shock absorber A and liquid shock absorber could not be used.

Figs.10,11,12 Frequency curves for shock absorbers at various rolling speeds.